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FLARE STARS AS A POSSIBLE SOURCE OF COSMIC
X-RAY EMISSION

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SUMMARY

The entire hypothesis is based upon the assumption that the flares in dwarf-stars of later types may be induced by transformation of infrared quanta of star's natural emission, this transformation being itself the result of reverse Compton effect. The total power of the star in the X-ray band is computed on that basis. Applying it to type-M2— M6 stars for various temperatures of the star, and comparing the results with the total flux of X-ray quanta emitted by the solar corona, the author concludes that even with the assumption that only one percent of the total number of infrared quanta passes into the X-ray region, the power of X-ray emission in flare stars of later types is one million times greater than that of Sun's radiation.

In order to verify the hypothesis brought forth, the author suggests a regular "X-ray patrol" of the sky with the aid of specialized Earth's X-ray satellites".

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There is basis to assume that in specific cases the flare stars of later type may be possible sources of X-ray emission from outer space. We have in view the fact of appearance during some flares of the emission line 4686 Å of the twice ionized helium. This is evidence of the fact that at time of flare there exist in the atmosphere of the given star either an ionizing radiation (shorter than 228 Å) of sufficient power, provided the helium ionization is induced by photons, or equivalent energetic particles (electrons) if the ionization is induced by collisions.

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* VSPYKHIVAYUSHCHIYE ZVEZDY KAK VOZMOZHNYY ISTOCHNIK KOSMICHESKOGO RENTGENOVSKOGO IZLUCHENIYA.

In either case it is difficult to assume that the spectrum of the ionizing
agent is broken immediately beyond
the limit of 228 Å; it may much
rather extend to the soft Roentgen
region (shorter than 100 Å).

An attempt has been made
in [1] to demonstrate that the
continuous emission event or the
foare in dward-stars of later types
may be induced by the transformation
of infrared quanta of star's natural
emission. The transformation itself
takes place by the strength of the

Fig. 1. - Theoretical spectrum in the
far ultraviolet at flare of type-M5
star (T = 2 800° K).

reverse Compton-effect, that is, the collision of infrared quanta with the
so-called fast electrons, whose energy is only a fraction greater than
the proper energy ($E > 5 \cdot 10^5$ ev). Such electrons appear avove the photo-
sphere as a result of ejection of intrastellar matter. It was shown else-
where [2] that the same process, that is, the transformation of infrared
quanta may be the cause of excitation of hydrogen, helium, and possibly of
other elements' emission lines in flare stars.

As an example, we illustrated in Fig. 1 the curves of energy distri-
bution in the continuous spectrum of the type-M5 flare star (T = 2 800° K)
at values $\mu^2 = 50$ and 100, where μ is the dimensionless energy of a fast
electron ($\mu = E/mc^2$). As may be seen from Fig. 1, in the case most fa-
vorable for the excitation of the line 4686 He II, that is, at $\mu^2 = 100$,
the continuous emission spectrum extends in reality rather far beyond the dual
helium ionization boundary ($\lambda < 228$ Å) and reaches the soft Roentgen region.
That is why the consideration of the problem of X-ray emission by flare
stars is of interest.

The significance of the reverse Compton-effect consists, as is well
known, in that at collision of a quantum with an electron, whose energy is μ,
there takes place a frequency change from ν' to ν, with, at the same time,
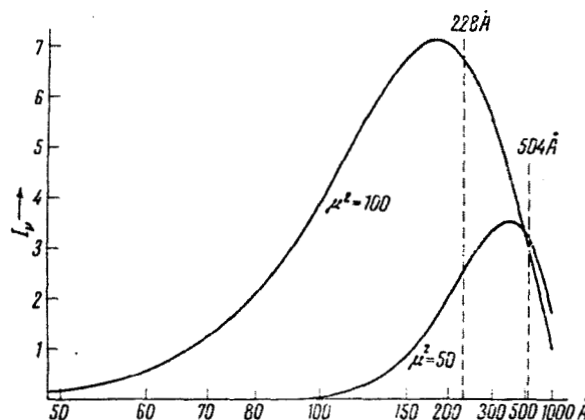
$$\nu \simeq \nu'\mu^2. \qquad (1)$$

It follows from this correlation that for great values of μ it is possible to obtain an X-ray quantum of frequency ν from any infrared quantum of frequency ν'. That is why, with a sufficient reserve of infrared quanta in the spectrum of the given star and in the presence of a certain number of fast electrons above the photosphere, there may emerge X-ray quanta in a number sufficient to make their detection possible.

Let us write, first of all, the law of energy distribution in the X-ray band of the spectrum. In the general case this law for an arbitrary frequency ν has the approximate form

$$I_\nu(\tau, \mu) = B_\nu(T) e^{-\tau} + \frac{1}{4\pi} \mu^2 B_{\nu'}(T) \tau e^{-\tau}, \qquad (2)$$

where $I_\nu(\tau, \mu)$ is the emission intensity in the frequency ν of the electron

Fig. 2. - Theoretical spectrum in the X-ray band during a powerful flare of a type-M5 star (T = 2800°K)

gas emerging from the layer; T is the effective temperature of the photosphere; τ is the effective optical thickness of the electron gas layer: $\tau = \sigma_e N$, where $\sigma_e = 6.65 \cdot 10^{-25}$ cm² is the Thomson scattering coefficient. N is the number of fast electrons per 1 cm² of the layer ($\tau = 0$ at the photosphere surface or at the base of the electron gas layer).

$B_\nu(T)$ and $B_{\nu'}(T)$ are Planck functions, with the necessity, at the same time, to effect in the second case the substitution $\nu' = \nu / \mu^2$.

At sufficiently great values of μ or at $\nu \gg \nu'$, we have from (2)

$$I_\nu(\tau, \mu) \approx \frac{1}{4\pi} \mu^2 B_{\nu'}(T) \tau e^{-\tau}. \qquad (3)$$

Substituting the value of B (T), we find for the law of emission intensity distribution in the X-ray band

$$I_\nu(\mu) \sim \mu^2 \frac{(\nu/\mu^2)^3}{\exp\left(\frac{h}{kT} \frac{\nu}{\mu^2}\right) - 1} . \qquad (4)$$
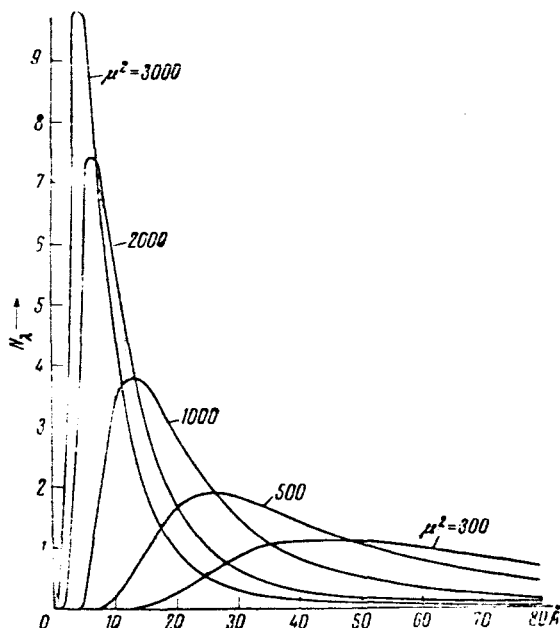
Note that although the absolute value of intensity depends in this case on τ (with, at the same time, at $\tau = 1$, $I_\nu(\tau, \mu) = \max$) the distribution of energy itself by frequency is independent from τ.

Plotted in Fig. 2 are the values of **N** found on the basis of the formula (4), representing the number of X-ray quanta (in arbitrary units) in the unitary interval of wavelengths emereging at type-M5 star's flare. It follows from this figure that the perceptible part of star's infrared quanta pass into the soft Roentgen region ($\lambda \sim 50$ Å) already at $\mu^2 = 300$, that is, at electron energy $E \sim 10^7$ ev. At $\mu^2 = 1000$ ($E \sim 1.6 \cdot 10^7$ ev the X-radiation maximum is already in $\lambda \sim 10 - 20$ Å, and at $\mu^2 = 3000$ ($E \sim 2.8 \cdot 10^7$ ev) this maximum is situated near $\lambda \sim 5$ Å.

What, despite this, is the theoretical emitting capability of a flare star of, say, type-M5, in the X-ray band, if one bears in mind the above expounded ideas? But in the final resort, the possibility of detecting the given star resides precisely in the quality of source's X-ray emission at time of its flare.

The power of X-ray emission of the star at flare depends first of all on the total number of infrared quanta N_f, emitted by the star in one second. We have :

$$N_f = 4\pi R_\bullet^2 \int_0^\infty \frac{B_\nu(T)}{h\nu}\,d\nu = 4\pi R_\bullet^2 \frac{2}{c^2} \int_0^\infty \frac{\nu^2 d\nu}{\exp(h\nu/kT) - 1} = 4\pi R_\bullet^2 C T^3 \quad \text{quantum/sec} \quad (5)$$

where R is the radius of the star

$$C = \frac{2}{c^2}\left(\frac{k}{h}\right)^3 \int_0^\infty \frac{x^2 dx}{e^x - 1} = 4{,}65 \cdot 10^{10}.$$

Let only the part α of the total number of infrared quanta N_f be passing into the Roentgen region as a result of the reverse Compton-effect. We shall then have for the total power of the star, N_R in the X-ray band

$$N_R = \alpha N_f = \alpha 4\pi R_\bullet^2 C T^3 \quad \text{quantum.sec} \quad (6)$$

We compiled in the third column of Table 1 [next page] the values of N_R for various temperatures T of the star in the assumption that only one percent (1%) of the total number of the infrared quanta passes into the Roentgen radiation region, that is $\alpha = 0.01$. It was admitted in the computations that $R_\bullet = 0{,}4\,R_\odot \approx 3 \cdot 10^{10}$ cm for all the four types of stars.

T A B L E 1

Power of X-ray emission, N and of
the flux N   of X-ray quanta during flares of Type M6-G1 stars

T, °K	N_f quantum/sec	N_R ($\alpha = 0.01$) quantum/sec	N_r ($\alpha = 0.01$) quantum/sec
2 500 M6	$\cdot 10^{43}$	0.8 $\cdot 10^{41}$	1.8
3 000 M2	1.4	1.4	3.1
4 000 K0	3.3	3.3	7.5
5 000 G1	6.6	6.6	14.5

As follows from the data of this Table 1, $N_R \sim 10^{41}$ quantum/sec
as an average of the type M2 — M6 stars. In order to arrive at some repre-
sentation as to how great or small this power is, we shall compare it with
the integral flux of X-ray quanta emitted by the solar corona. The total
energy emitted by the solar corona in the X-ray band (in $\lambda \sim 20$ Å) at coro-
na temperature $\sim 10^6$ °K is, according to Elvert [3], $I_\odot \approx 5 \cdot 10^{25}$ erg/sec,
or $N_\odot \approx 5 \cdot 10^{34}$ quantum/sec. Hence it follows that the power of X-ray emis-
sion during flare of later type-stars, is one million times greater (Table 1)
than the power of Sun's X-ray emission even at $\alpha = 0.01$.

Denoting by $\underline{r}$ the distance from the flaring star to us, we shall
have for the X-ray flux N_r, having reached the ground observer

$$N_r = N_R / 4\pi r^2 = \alpha C (R_* / r)^2 T^3 \quad \text{quantum/cm}^2 \text{ sec}$$

According to Haro [4], the individual flare star of the type Uv of
Cetus are situated in the zone around the Sun, of which the radius is ~ 20 ps.
That is why we shall admit $r \approx 6 \cdot 10^{19}$ cm. In the latter column of Table 1
we compiled the values of N_r, computed with the aid of (7) : we obtain as an
average $N_r \sim 3$ quantum/cm$^2 \cdot$ sec for stars of later types and at $\alpha = 0.01$.
This value is within the threshold response of the best X-ray detectors
applied for the detection of point or extended sources of cosmic X-ray
radiation.

As is well known, the best studied flare stars are situated at only
a distance of 7 ps from the Sun [5]. Then, the estimate made by us can be
increased by nearly one order.

Are there any practical possibilities of verifying the hypothesis brought forth? Leaving aside the theoretically possible, the most direct, but so far very uneasily-materializable means of verifying this assumption, that is, the launching of a rocket with X-ray detectors aboard beyond the limits of the Earth's atmosphere at the time of flare of any star, we may indicate the following indirect possibility.

The fact of the matter is that the X-ray emission, according to the above concensus, may appear in stars of later types only at time of their flares; during the remaining time there will be no such emission. That is why, by realizing a regular scanning of the sky in the X-ray band — a sort of "X-radiation patrol" with the help of specialized "X-ray satellites" of the Earth, we shall be able to detect among them the variables, provided of course they exist. And although the variability of any Roentgen source of cosmic origin may be induced by other causes too, we shall nevertheless be able to assert with a sufficiently high probability that they may be flare stars.

⁝⁝⁝   T H E   E N D   ⁝⁝⁝

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